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OCTOBER 1954



# EFFECT ON DRAG OF TWO STABLE FLOW CONFIGURATIONS OVER THE NOSE SPIKE OF THE 90MM T316 PROJECTILE

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Research and Development Project No. TB3-0108

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ABERDEEN PROVING GROUND, MARYLAND

B A L L I S T I C   R E S E A R C H   L A B O R A T O R I E S

TECHNICAL NOTE NO. 955

BGKarpov/MJPiddington/plg
Aberdeen Proving Ground, Md.
October 1954

# EFFECT ON DRAG OF TWO STABLE FLOW CONFIGURATIONS OVER THE NOSE SPIKE OF THE 90MM T316 PROJECTILE

## ABSTRACT

Shadowgraphs of the 90mm T316 projectiles in free flight, obtained in the Transonic Range, showed that two different types of flow, both apparently stable, can exist over the cylindrical nose spike of this configuration. The two flows result in a markedly different drag characteristics, differing by as much as 50%. Results of experiments with modified spikes, designed to assure a low drag flow, are briefly described.

In connection with the development of the 90mm T316 configuration which is being carried by the Frankford Arsenal with close cooperation of the Development and Proof Services at the Aberdeen Proving Ground, the Exterior Ballistics Laboratory was requested to fire a limited program with this shell through its Transonic Range. Ten rounds were allocated for this purpose and were fired at three different Mach numbers: 2.4, 2.0, and 1.5. Plate 1 shows the general appearance of this shell.

Examination of the shadowgraphs showed that on some rounds the flow separated immediately off the spike, on others it remained attached for some distance along the spike and then separated. Each type of flow appeared to be stable, i.e., it persisted throughout the photographed range without change. The two types of flow are shown on Plates 2 and 3. Similar phenomenon was first observed in the wind tunnel by A. S. Platou[1] at considerably lower Reynold's numbers, $0.4 \times 10^6$. The Reynold's numbers of the present firings, based on overall length are: $R_e = 14.2 \times 10^6 M$ where M is Mach number.

The two types of flow produce markedly different retardations. The drag coefficients, $C_D = \frac{8}{\pi} K_D$, are illustrated in Figure 1. It should be noted that a group of rounds of high drag flow at $M = 2.4$ show considerable dispersion which correlates well with the position of actual separation over the spike. If the flow separates immediately at the nose, the drag coefficients are much more consistent.

Since the occurrence of either type of flow appears to be of a statistical nature, caused by unknown conditions, a given group of rounds fired on a target might contain both species. With markedly different drag characteristics, the two groups will gradually separate, principally in a vertical plane, by as much as three mils at 2000 yards. The vertical target will then contain both high and low rounds thus jeopardizing what otherwise might be a good dispersion pattern. Clearly, it is desirable to fix the flow over the spike in such a way that only one type of flow occurred and preferably of a lower drag type.

Frankford Arsenal provided ten additional rounds with the spikes cut off at the step (see Plate 1). Aluminum extensions of the spike were made incorporating various simple devices for promoting flow separation at the nose. These devices were: a) a ring, b) truncated cone, and c) serrated cone which resulted from machining simple treads at the nose of the spike and then machining these to a form of a truncated cone for reducing the drag. These devices are illustrated in Figure 2. These modified rounds were fired at about 3300 feet per second. All devices separated the flow and, hence, performed satisfactorily. Plates 5, 6, and 7 illustrate the resulting flows which persisted throughout the observed range and appeared to be stable. Two unmodified rounds were fired as a control. The drag coefficients of unmodified rounds, which happened to have high drag flows, were about 20% higher than the drag coefficients of modified rounds which all had substantially similar drags.

One round was fired with longer spike with a ring. The flow over the spike was observed to be unsteady, changing its characteristics over the observed range (see Plates 7a and 7b). Hence, if longer nose spike is desired for greater stand-off, additional experiments are necessary for developing a device which will assure a desirable flow.

To illustrate the effect on targets at 1000 and 2000 yards of high (h) and low (l) drag trajectories, Table 1 was computed using Siacci Tables based on standard drag functions of type 2. The form factor for high drag rounds is $i_2 = 2.74$; it varied from 2.7 at M = 2.0 to 2.8 at M = 2.9, the range of Mach numbers covered by present firings. The low drag rounds cover wider range of velocities from Mach numbers 1.5 to 2.9 and the form factor varied from 1.7 at M = 1.5 to 2.3 at M = 2.9. For computation of low drag trajectories an average form factor was used, $i_2 = 1.95$.

TABLE I

Trajectory Characteristics of High and Low Drag Rounds of the 90mm T316 Shell

1000 Yards

| M. V. fps | 3200 | | 3600 | | 4000 | |
|---|---|---|---|---|---|---|
| | h | l | h | l | h | l |
| t, sec | 1.13 | 1.06 | .99 | .94 | .87 | .84 |
| u, fps | 2211 | 2474 | 2570 | 2845 | 2934 | 3220 |
| $\theta_0$, mils | 6.1 | 5.7 | 4.7 | 4.4 | 3.8 | 3.6 |
| $\omega$, mils | 7.9 | 6.8 | 6.0 | 5.2 | 4.5 | 4.1 |
| D, ft | 17.9 | 16.4 | 13.7 | 13.0 | 11.1 | 10.5 |

2000 Yards

| M. V. fps | 3200 | | 3600 | | 4000 | |
|---|---|---|---|---|---|---|
| | h | l | h | l | h | l |
| t, sec | 2.86 | 2.48 | 2.44 | 2.15 | 2.12 | 1.89 |
| u, fps | 1343 | 1808 | 1652 | 2148 | 1974 | 2493 |
| $\theta_0$, mils | 17.1 | 14.0 | 12.7 | 10.7 | 9.8 | 8.4 |
| $\omega$, mils | 30.5 | 20.5 | 21.3 | 15.1 | 15.7 | 11.5 |
| D, ft | 100.1 | 82.4 | 74.8 | 62.9 | 57.7 | 49.5 |

t = time of flight

u = remaining velocity

$\theta_0$ = quadrant elevation

$\omega$ = angle of fall

D = drop

The table shows clearly that if the same type of flow persists throughout the trajectory, considerable vertical spread between impacts on the target may be encountered, which will become quite pronounced at longer ranges.

Therefore, it is recommended that in order to preserve consistency in the performance of these rounds, the present spiked nose be modified by incorporating a flow separating device either of tested variety or of some other type which might be easier to manufacture. Of course, a new device again will have to be tested to prove its worth.

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## REFERENCES


1. Platou, A. S., Body Nose Shapes for Obtaining High Static Stability, BRL Memorandum Report No. 592 (1952) (C).

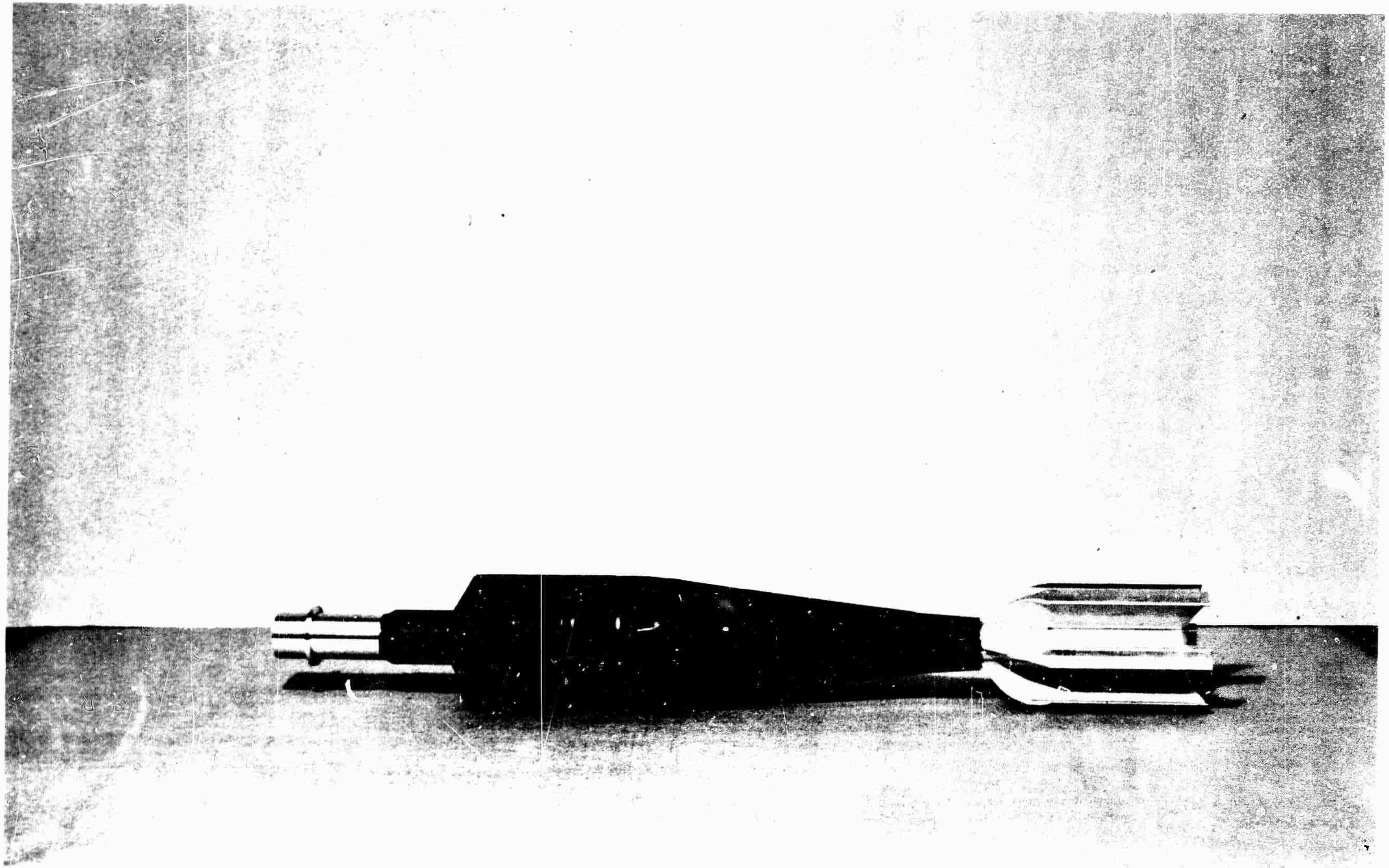


Plate 1 Photo of 90 mm T316 E4 Shell, Modified

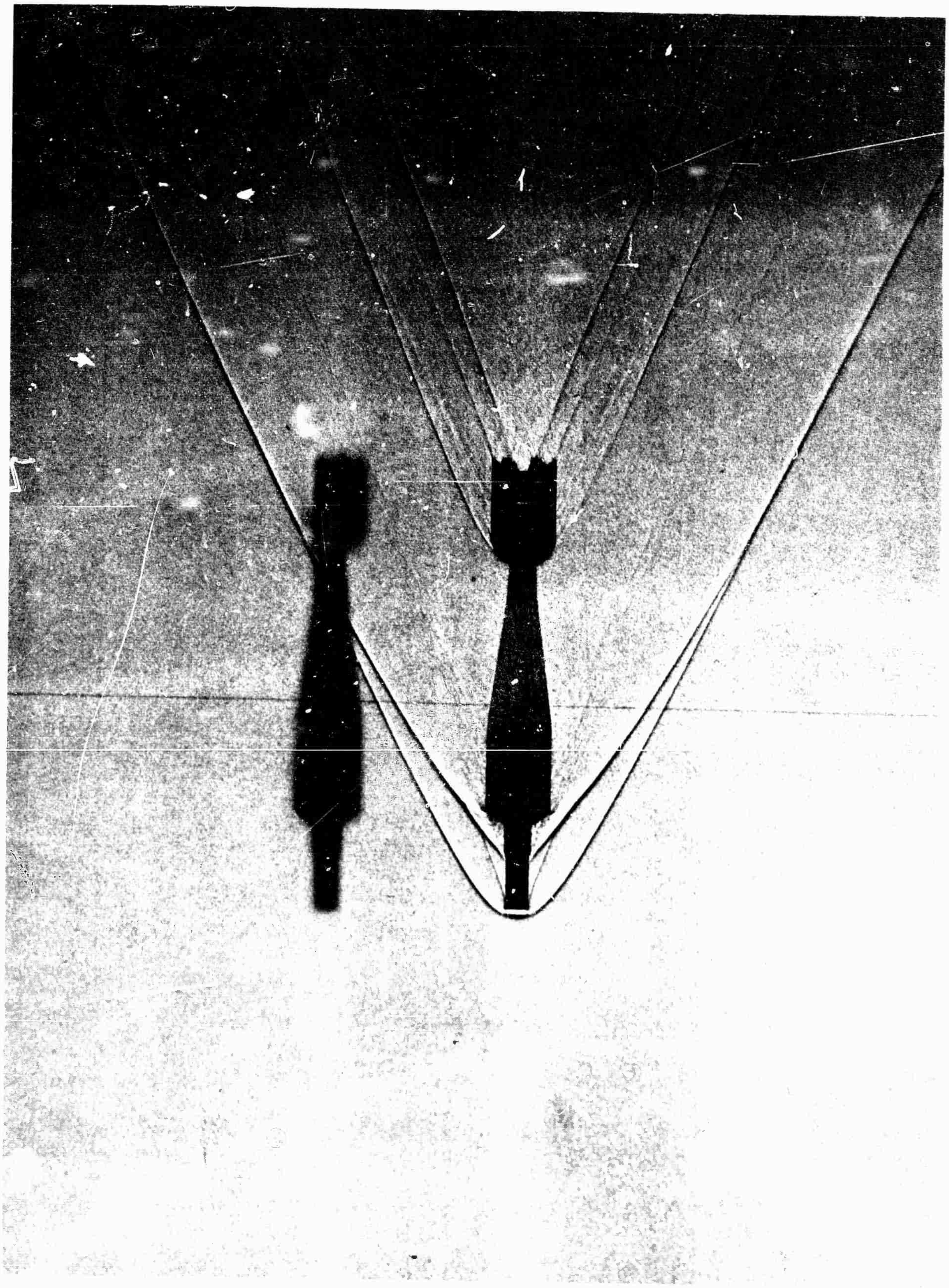


Plate 2 High drag flow. $M = 2.44$, $C_D = .782$

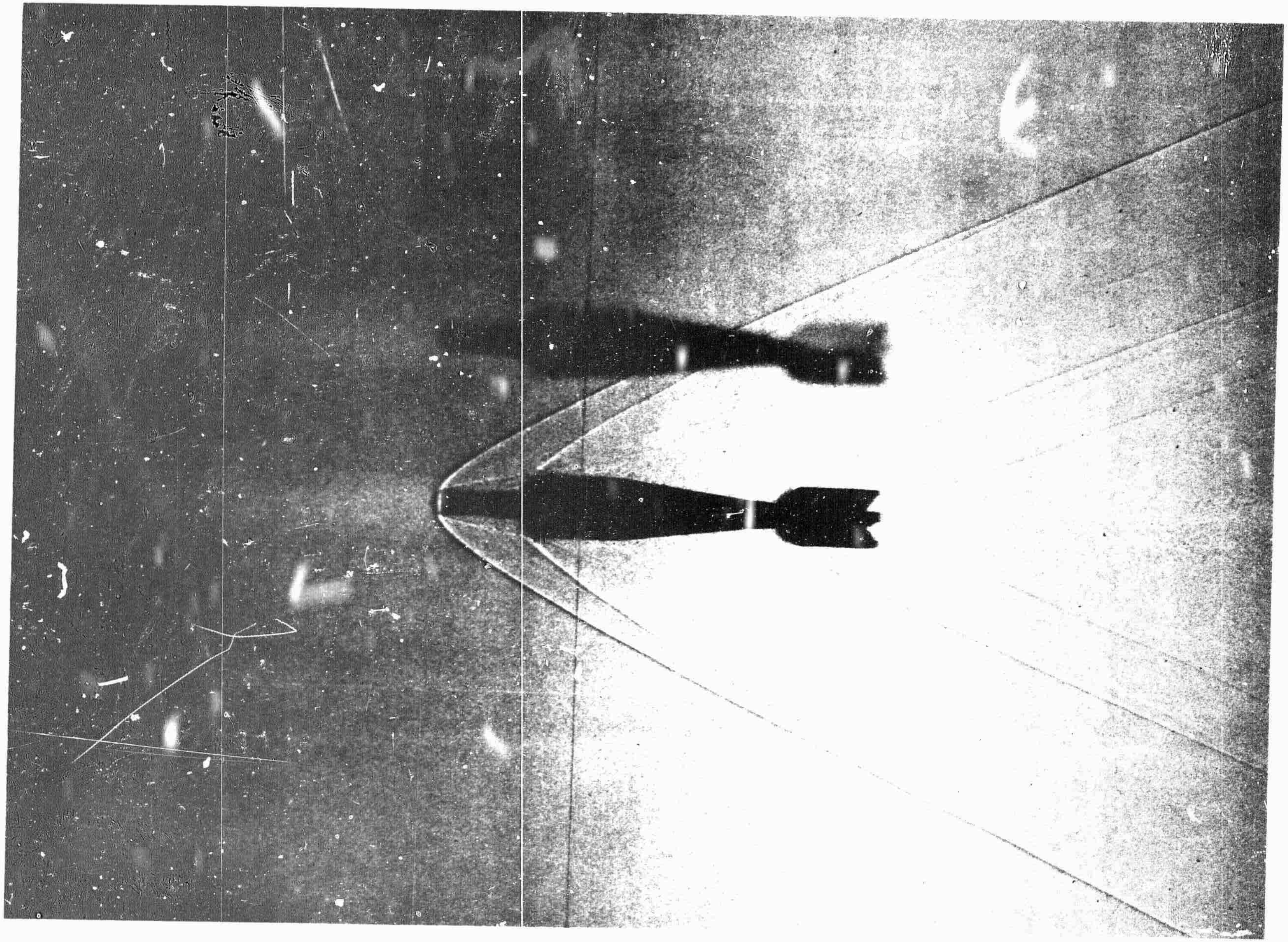


Plate 3 w drag flow. $M = 2.43$, $C_D = .534$

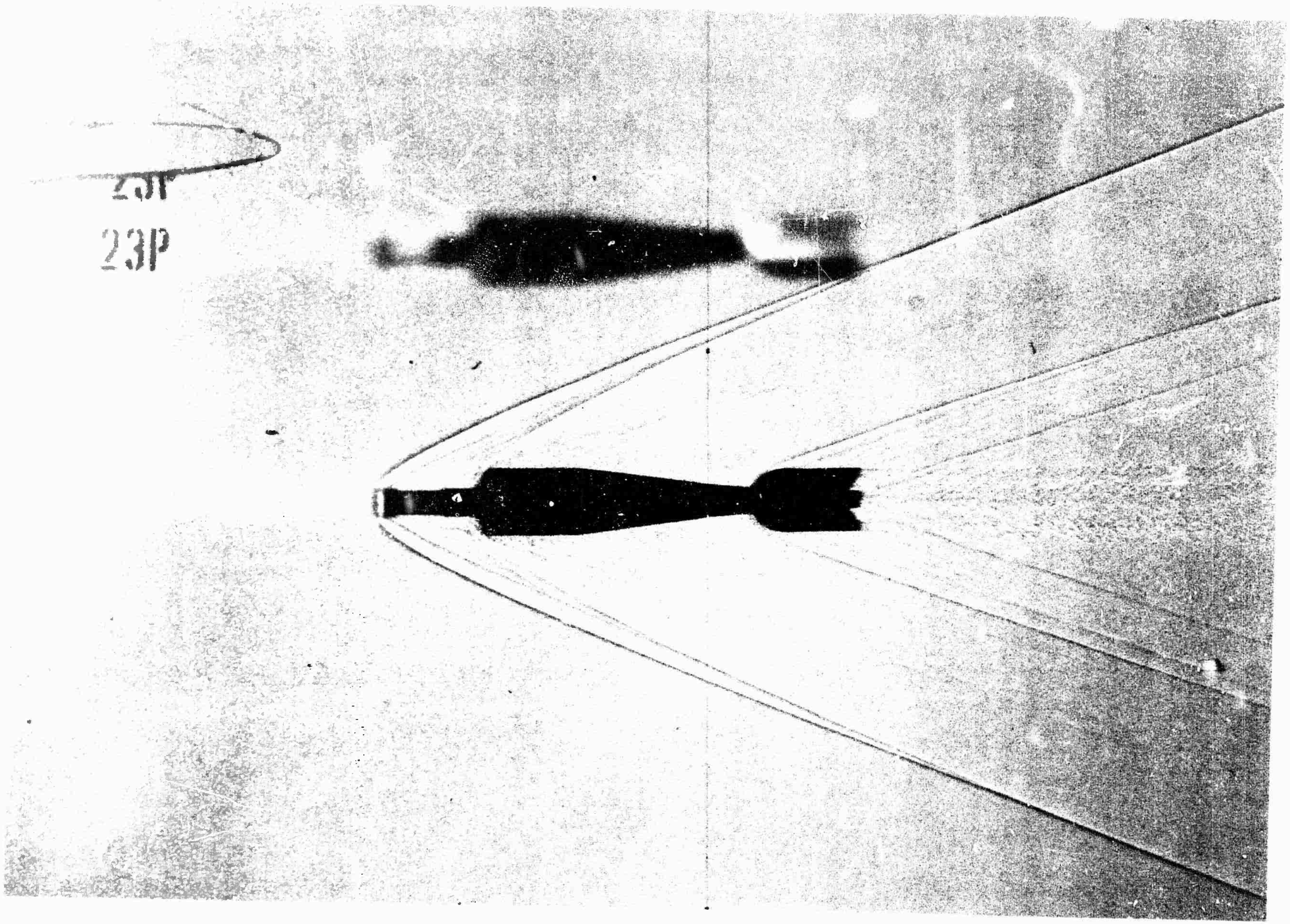



Plate 5 Low drag flow. Truncated Cone. $M = 2.93$, $C_D = .529$

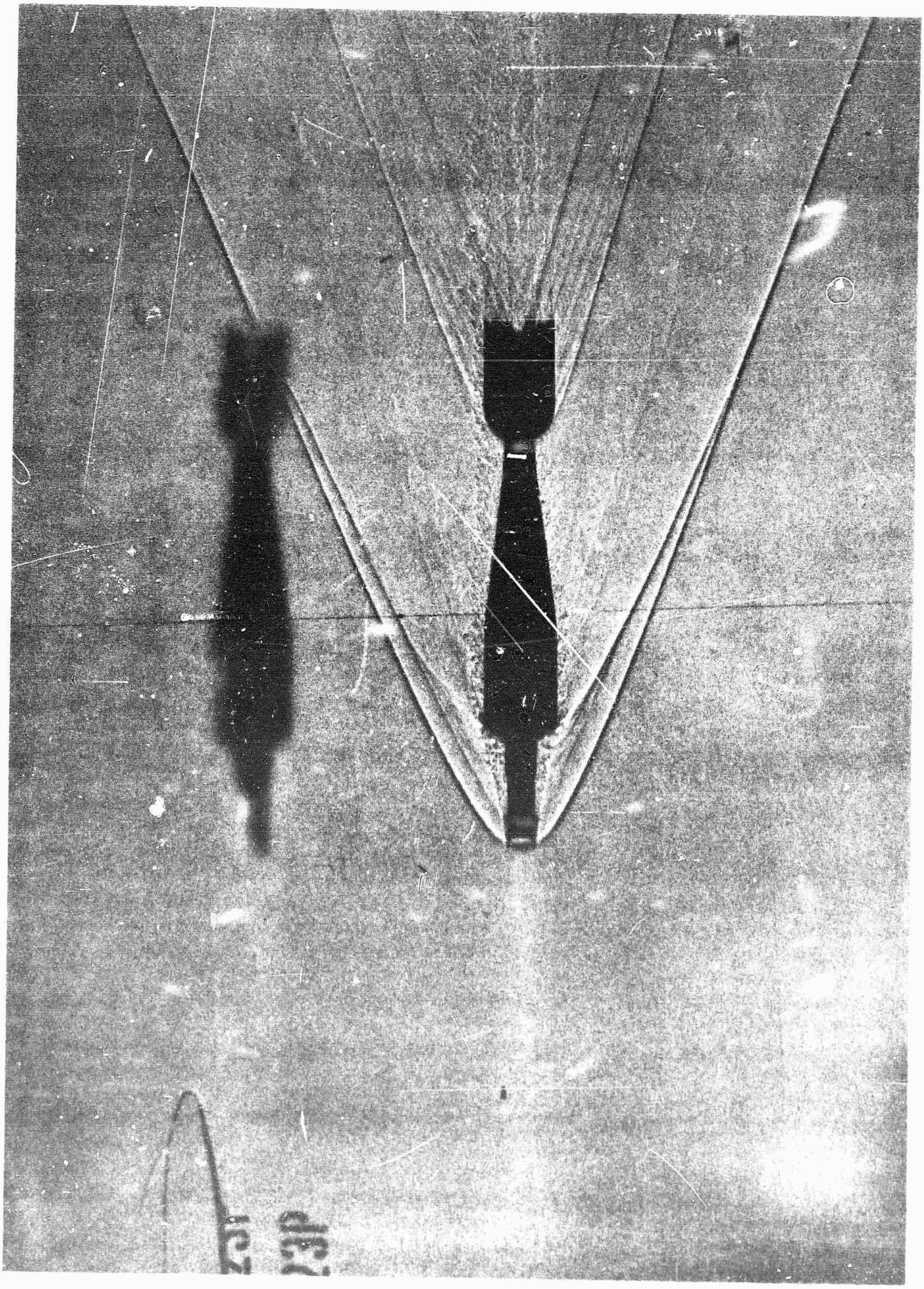


Plate 4 Low drag flow. $M = 2.93$, $C_D = .491$

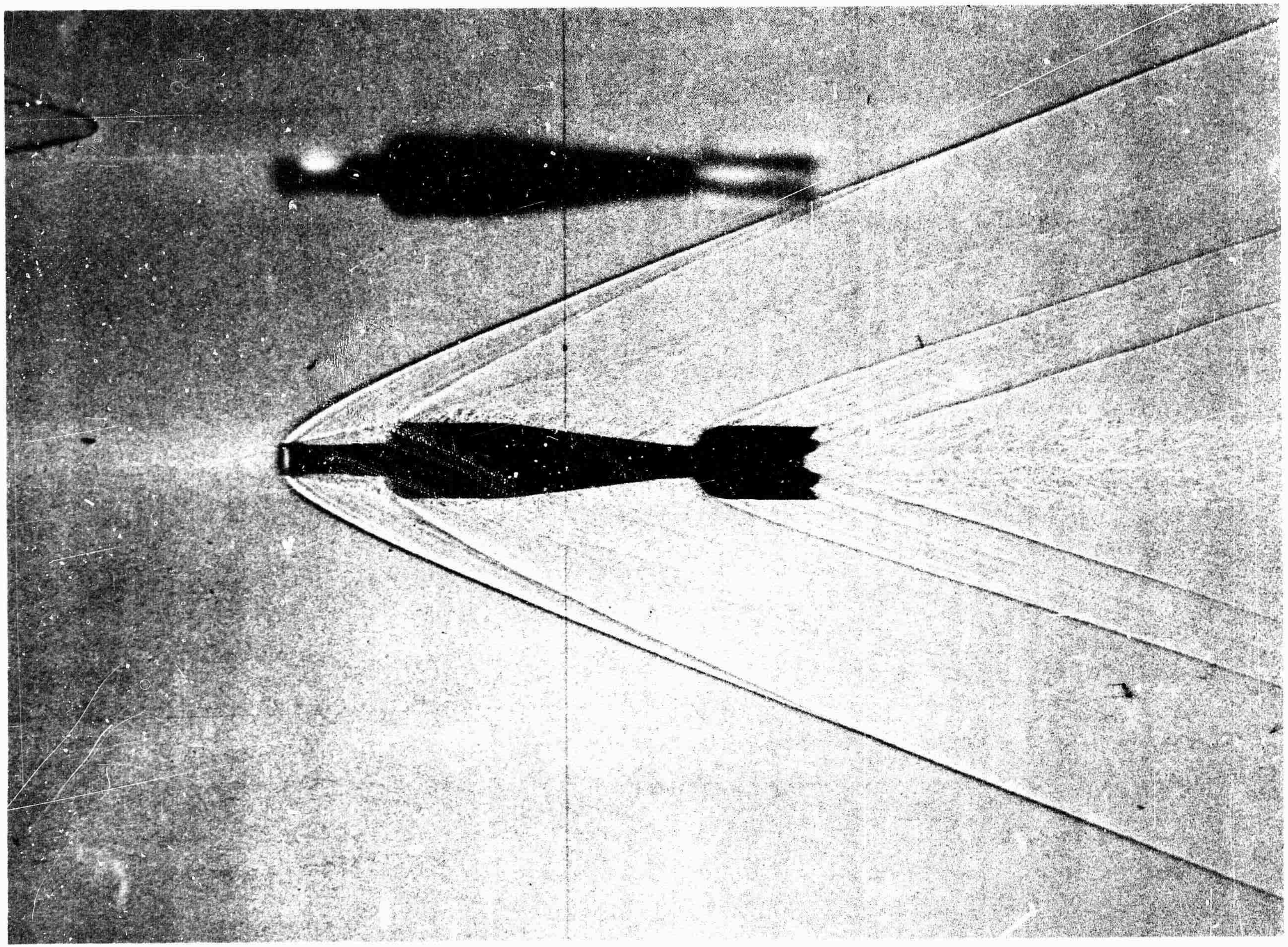


Plate 6 Low drag flow. Serrated Cone. $M = 2.94$, $C_D = .471$

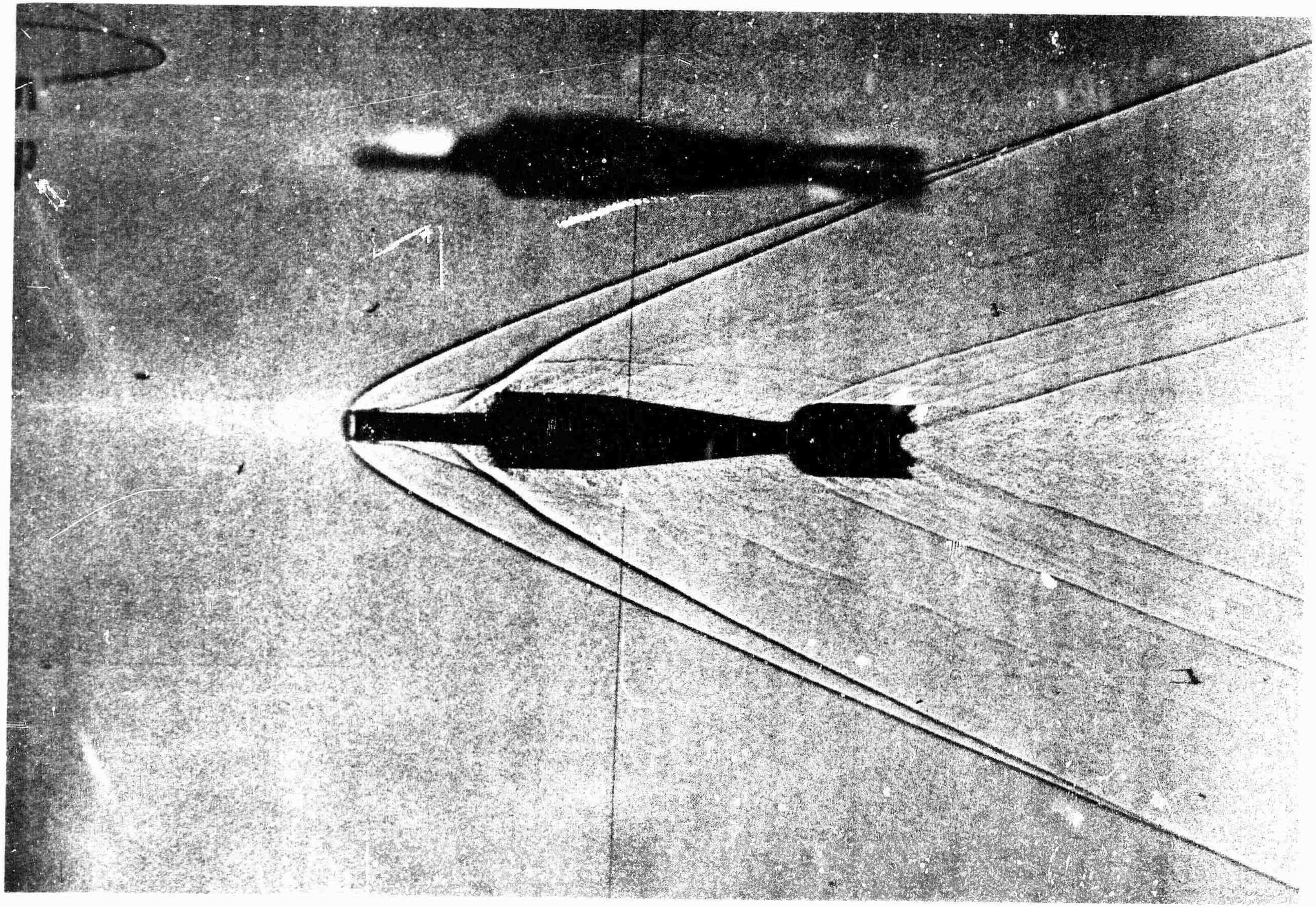


Plate 7a Long Spike with Ring. Unsteady **Flow**. Round 2944, Station 23.

$M = 2.90$, $C_D = .672$

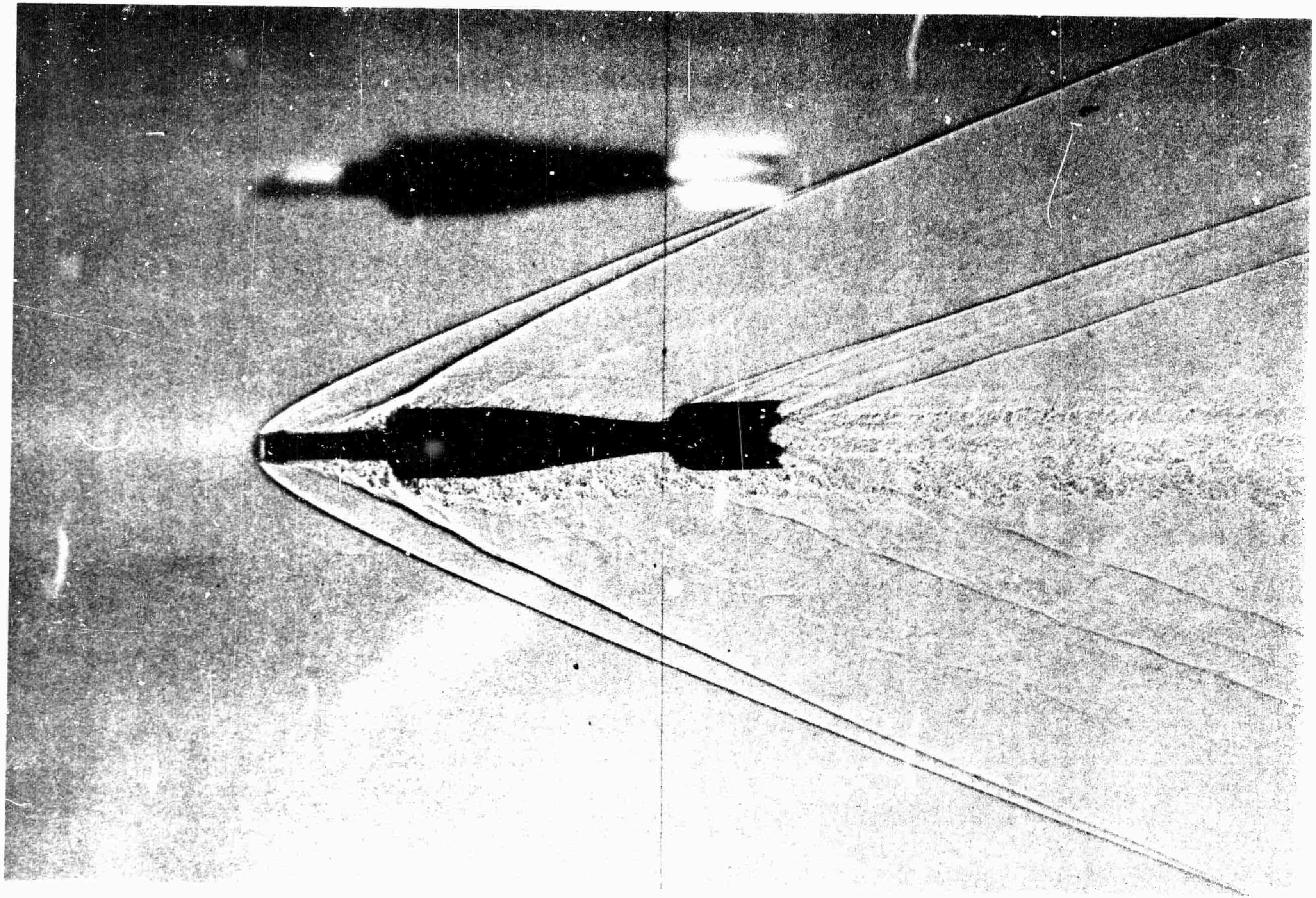
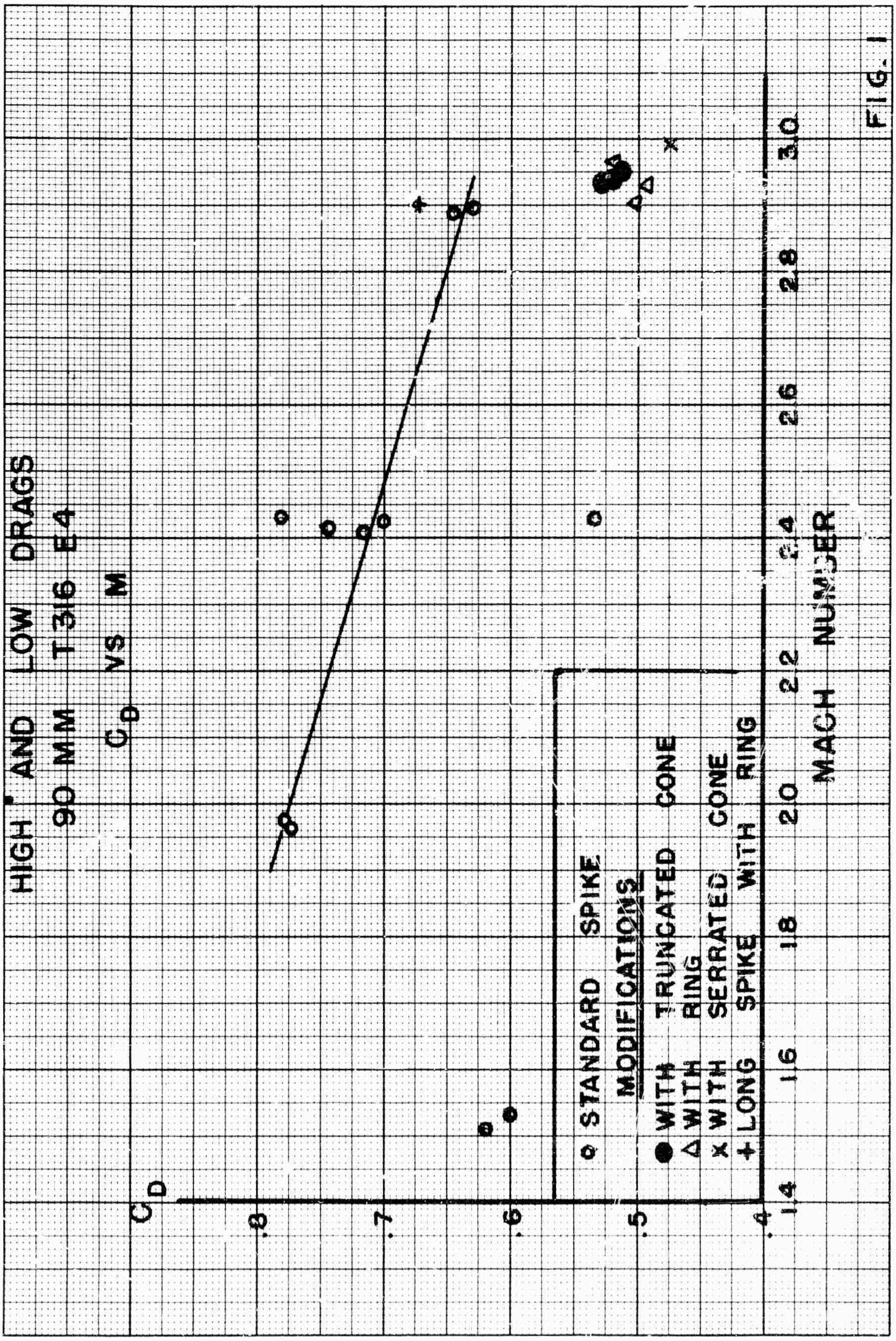
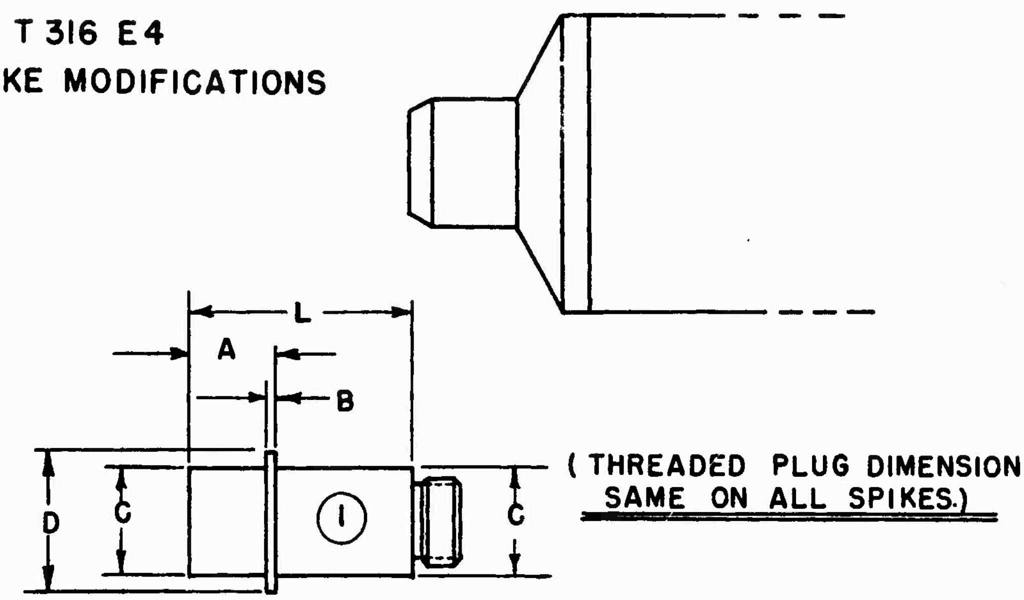


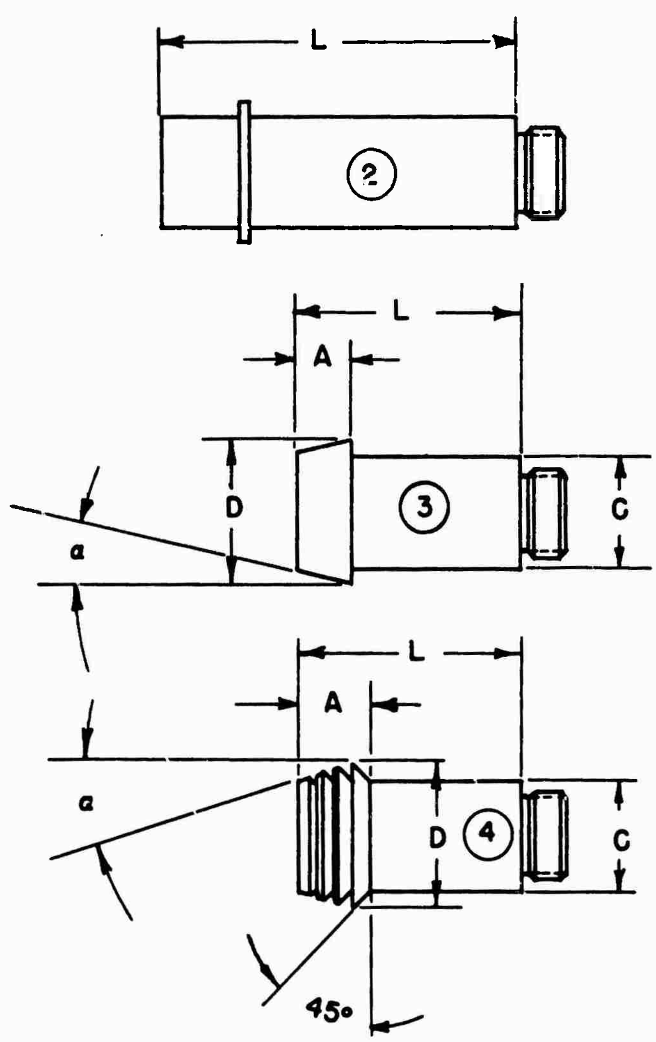
Plate 7b  Long Spike with Ring. Unsteady Flow. Round 2944, Station 34.

$M = 2.90$, $C_D = .672$


HIGH AND LOW DRAGS
90 MM T316 E4
$C_D$ VS M
$C_D$
.8
.7
.6
.5
.4
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
MACH NUMBER
o STANDARD SPIKE
MODIFICATIONS
● WITH TRUNCATED CONE
Δ WITH RING
x WITH SERRATED CONE
+ LONG SPIKE WITH RING
FIG. 1

90 MM T 316 E4
NOSE SPIKE MODIFICATIONS




ALL DIMENSIONS IN INCHES

| SPIKE NO. | 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| L" | 2.933 | 4.433 | 2.933 | 2.933 |
| A" | 0.95 | 0.95 | .705 | .798 |
| B" | .125 | .125 | — | — |
| C" | 1.281 | 1.281 | 1.281 | 1.281 |
| D" | 1.680 | 1.680 | 1.680 | 1.680 |
| a° | — | — | 12° 30' | 18° 26' |

FIG. 2